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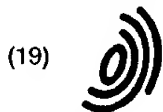
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(54) **Data manipulation and visualization apparatus for cellular network planning and operation**

(57) Data manipulation and visualization tools for simulating the planning and operation of one or more cellsites within a wireless network include an integrated database of cellsite information such as topographical, architectural, and RF propagation data. The tools retrieve and manipulate this data through graphical user interface software executed by a computing device. Using the graphical user interface, a user may simulate the operational characteristics of a cellsite, such as an antenna adjustment at the cellsite, and view cellsite parameters on a computer screen, such as the resulting RF propagation patterns from the antenna adjustment.

**EP 0 928 121 A2**

## Description

### Background of the Invention

[0001] The present invention relates generally to software tools for wireless networks, and more particularly to data manipulation and visualization tools with accompanying apparatus for planning, simulating, operating, and maintaining a cellsite in a wireless network.

[0002] The evolution of wireless communication technology has created a reliance on cellular phones, and more recently, personal communication systems (PCS) that allow a user to make a telephone call or check his E-mail from virtually anywhere in the world. Such a system generally consists of a network of cells, that is, a geographical service area covered by a single antenna or group of antennas. The antennas for one or more cells are located at a cellsite.

[0003] With the growing demand for more powerful and "user friendly" wireless communication devices, service providers are constantly upgrading their systems to maintain market share. Such upgrading transition may include adding antennas and other resources to their system to accommodate more users and provide better service coverage for subscribers. When adding antennas to an existing cellsite or while planning a new cellsite, service providers often run into problems.

[0004] One problem is the time and resources necessary to plan and operate a cellsite. Radio frequency (RF) components (e.g., RF propagation) define the area of coverage for one or more cells. For example, an urban service provider may use one or more cells to provide wireless communication services to subscribers for a ten-block radius. To provide this service coverage, service providers typically position one or more antennas at the highest point of the cellsite (e.g., using a cellsite tower) to facilitate RF coverage for a large geographical area (e.g., a ten-block radius). The antenna then connects to an RF transmitter and receiver to carry voice or data signals between the cell and subscriber. Some service providers use omnidirectional antennas which provide 360 degrees of RF coverage for the cell while others may use directional antennas that provide RF coverage only for a sector of the cell. A sector is a geographical area, having a distinct size and shape, covered by a single antenna. For example, a service provider may use three antennas to provide 360 degrees of RF coverage for a cell with each antenna providing 120 degrees of coverage. Antenna selection usually depends on the carrier interface used by the service provider (e.g., time division multiple access (TDMA), code division multiple access (CDMA), and global system for mobile (GSM)). The carrier interface typically determines the number of voice or data channels supported by the cell.

[0005] Service providers often have difficulty planning and troubleshooting RF coverage for one or more sectors in a reasonable period of time. Typically, this difficulty

stems from using trial and error techniques to plan cell operation and troubleshoot cellsite problems. For example, service providers often dispatch technicians to a cellsite to manually adjust an antenna, and then test RF coverage to see if the manual adjustments corrected a detected RF coverage problem. If the RF coverage is not satisfactory, the technician must keep manually adjusting and testing the antenna until the RF coverage is within a desired tolerance. This manner of setting and testing the desired RF coverage is very time consuming and often costly to service providers. In addition, inclement weather or other factors may thwart repeated attempts to manually adjust the antenna, causing delay in rendering the cellsite operational at the desired level of performance.

[0006] Another problem experienced by service providers is the inability to account for possible topographical or architectural obstructions when measuring RF coverage for one or more sectors. More detailed views of RF coverage in a variety of planes are necessary to plan and troubleshoot around these obstructions. For example, if an RF signal is obstructed by a tall building in an urban area, many current systems cannot determine the location and size of the obstruction relative to the placement of the transmitting antenna. By obtaining this information, antennas can be strategically placed or adjusted in order to minimize any "dead spots" in one or more sectors. Architectural and topographical information allow a service provider to locate the obstruction and adjust one or more antennas accordingly.

[0007] Finally, service providers currently use multiple RF voice channels to support the increasing number of wireless communication subscribers in high density areas (e.g., urban locations). These areas are typically covered by several antennas arranged vertically and/or horizontally on a cellsite tower. Due to the increased voice channels, it is often difficult for service providers to view the different layers of RF propagation corresponding to each voice channel supplied by the cell. That is, when viewing the RF propagation of a sector, service providers are currently unable to determine which antenna-based on its height or location on the tower--is responsible for supplying a particular voice channel. As a result of these shortcomings, service providers are unable to plan, maintain and troubleshooting RF propagation issues in an effective and cost-efficient manner.

[0008] Therefore, it is desirable to provide a wireless network planning tool that allows a service provider to effectively and efficiently plan RF coverage and troubleshoot RF propagation issues at a cellsite.

[0009] It is also desirable to provide a wireless network planning tool that accounts for topographical and architectural data when planning or adjusting RF coverage for a cellsite.

[0010] It is further desirable to provide a wireless network planning tool that allows a service provider to view the different layers of RF propagation data corresponding to each RF voice channel supplied by a cell.

[0011] Additional desires, features and advantages of the invention are set forth in the following description, apparent from the description, or may be learned by practicing the invention.

#### Summary of the Invention

[0012] Systems and methods consistent with the present invention meet these desires by providing data manipulation and visualization tools with accompanying apparatus for planning, simulating, operating, and maintaining a cellsite in a wireless network.

[0013] Specifically, a data manipulation and visualization tool for simulating a operational characteristic of a cellsite comprises means for storing data corresponding to the operational characteristic of the cellsite; means for displaying the data; means for manipulating the data to simulate the operational characteristic of the cellsite; and means for viewing the simulated operation of the cellsite.

[0014] A method of data manipulation and visualization for simulating an operational characteristic of a cellsite, comprises the steps of storing data corresponding to the operational characteristic of the cellsite; displaying the data; manipulating the data to simulate the operational characteristic of the cellsite; and viewing the simulated operation of the cellsite.

[0015] Both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

#### Brief Description of the Drawings

[0016] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention and, together with the preceding general description and the following detailed description, explain the principles of the invention.

[0017] In the drawings:

Fig. 1 is a block diagram illustrating a network management system consistent with the present invention;

Fig. 2 is a flowchart illustrating a method of data manipulation and visualization consistent with the present invention;

Fig. 3a illustrates a plurality of simulated cellsite data consistent with the present invention;

Fig. 3b is a display information manager software tool for controlling the image intensity of simulated cellsite data shown in Fig. 3a;

Fig. 3c is a cellsite tuning software tool for tuning one or more antennas located in the simulated cellsite of Fig. 3a;

Fig. 4 is a flowchart illustrating a method of tuning an antenna at a cellsite;

Fig. 5a illustrates a cross-sectional viewer software tool for simulating a cross-sectional view of RF propagation at a cellsite consistent with the present invention;

Fig. 5b is a simulated cross-sectional view of radio frequency (RF) propagation at the cellsite illustrated in Fig. 5a;

Fig. 6 is a flowchart illustrating a method of selecting a cross-sectional area of a cellsite for viewing;

Fig. 7 illustrates a sector cellsite browser software tool for simulating a plurality of RF propagation layers corresponding to respective antenna groupings at a cellsite consistent with the present invention;

Fig. 8 is a flowchart illustrating a method of manipulating and displaying RF propagation data for one or more selected antenna groups at a cellsite;

Fig. 9 illustrates a network browser software tool for simulating sub-networks associated with a network node consistent with the present invention;

Fig. 10a illustrates a historical traffic performance viewer software tool for simulating a subscriber's location within or around a cellsite when placing a call consistent with the present invention; and

Fig. 10b is a control screen for controlling parameters associated with the simulated cellsite of Fig. 10a over a period of time.

#### Detailed Description of the Invention

[0018] Reference will now be made in detail to the construction and operation of preferred embodiments consistent with the present invention that are illustrated in the accompanying drawings. In those drawings, like elements and operations are designated with the same reference numbers.

[0019] Embodiments consistent with the present invention are directed to software tools for manipulating and visualizing complex data. These software tools include a display information manager, cellsite tuner, cross-sectional viewer, data browser, cellsite data browser, and historical traffic performance viewer. Each of these tools include graphical user interfaces that are adaptable to a variety of applications relating to telecommunications, medicine, geography, or any other field that involves organizing, managing, and manipulating large amounts of complex data. For implementation purposes, the data manipulation and visualization tools described herein are directed to wireless communications technology, and more particularly, to network management systems for cellsites employing wireless communications technology. Where appropriate, alternative embodiments consistent with the present invention are described herein to identify other applications for the data manipulation and visualization tools. The alternative embodiments provide only a few examples of data manipulation and visualization tool applications and are not intended to be comprehensive.

[0020] Fig. 1 illustrates a network management system

100 consistent with the present invention. Network management system 100, located remotely or at a cell-site, provides a user (e.g., network manager) with the ability to simulate cellsite planning and operation using one or more of the above-noted software tools. The system includes an integrated database 120, computer system 140, graphical user interface 160, and communication device.

[0021] Integrated database 120 includes a variety of data corresponding to a cellsite (e.g., topographical data, architectural data, and RF propagation data). Database 120 preferably resides on a memory device, such as a hard drive, for storing large amounts of information. Data that is stored in database 120 may be updated or modified in any manner to maintain current cellsite information. In addition, database 120 may be expandable to accommodate additional information corresponding to one or more cellsites. Preferably, database 120 stores cellsite data in an integrated format to allow a user to retrieve and view different categories or types of cellsite data simultaneously. The data may include two-dimensional images (e.g., maps, plans, and photographic images), three-dimensional images (e.g., architectural clutter, and mechanical surface geometry), and operational measurements (e.g., data streams and formulas).

[0022] Computer system 140 is a high performance computer capable of processing complex graphical information. To achieve high performance, computer system 140 preferably includes a Pentium® processor (or equivalent) or greater, a memory, such as random access memory, and a high resolution display. Computer system 140 may be a stand alone computer or may be connected to a network having high performance capabilities (e.g., 100 base-t or ATM25). In addition, computer system 140 supports platform independent languages such as Java and HTML. Commercially available simulator software, such as software developed by Paradigm Simulations, Inc., can be executed on computer system 140 to simulate data received from database 120. The simulated data can be superimposed on one another and are viewable on a display of computer system 140 using a graphical user interface.

[0023] Graphical user interface 160 is a software program executed by computer system 140 that allows a user to manipulate data viewed on the display of computer system 140. Each software tool described herein uses graphical user interface 160 for data manipulation. To facilitate data manipulation, a mouse, keyboard, or other similar input device may be used. Graphical user interface 160 allows a user to interact with displayed data to change conditions or operations of the cellsite. Preferably, graphical user interface 160 is user-friendly (e.g., Windows-based) to allow the user to retrieve, manipulate and display cellsite information effectively on computer system 140 by simply selecting or controlling one or more icons using an input device.

[0024] Communication device 180 communicates

information between system 100 and a remote site. Specifically, communication device 180 retrieves information for storage, manipulation or simulation (e.g., RF propagation data) and sends system 100 information to a remote site. For example, when a network manager makes simulated changes to a cellsite antenna on system 100, the changes can be communicated to a cell-site through communication device 180 for implementation. Communication device 180 can be a wireless or wireline device depending on the application environment of system 100.

[0025] Fig. 2 is a flowchart illustrating a method of data manipulation and visualization consistent with the present invention. Initially, database 120 stores cellsite data, such as topographical, architectural and RF propagation data (step 200). Computer system 140 then retrieves and displays the data to a user (step 220). Subsequently, the user can manipulate data using graphical user interface 160 to simulate cellsite conditions or operations (step 240). Upon obtaining an optimum simulated cellsite condition or operation, a user can view the simulated condition or operation of the cell-site (step 260). In this manner, network management system 100 allows the user to simulate certain operations of a cellsite before making any manual adjustments to cellsite hardware (e.g., an antenna or power amplifier). This allows for more accurate cellsite planning and operation while reducing the amount of time needed to make cellsite adjustments.

[0026] Fig. 3a illustrates a plurality of simulated cell-site data consistent with the present invention. The cell-site data include topographical data 300, architectural data 305, street map data 310, radio frequency propagation data 315, surround line of site terrain data 320, cellsite location data 325, and subscriber data 330. These data are gathered and stored in database 120.

[0027] Topographical data 300 provide a topographical view of the geographical area in which the cellsite is located. Architectural data 305 provide an aerial view of buildings and other similar architecture located in or around the cellsite. Street map data 310 allow the user to view the street configuration within and around the cellsite. Topographical, architectural, and street map data are obtained by commercially known methods or from commercially available databases.

[0028] RF propagation data 315 provide an aerial view of RF coverage at a cellsite. Computer system 140 displays RF propagation data 315 as transparent to enable viewing of other cellsite information, such as topographical, architectural and street map data. Sonar mapping equipment (e.g., a radio receiver linked with a very precise timing system) may be used to measure and record RF propagation data at the cellsite. This equipment may also be used to determine the border or outer perimeter of RF coverage at the cellsite which is stored as surround line of site terrain data 320. Cellsite location data 325 illustrate the cellsite from which one or more antennas send and receive RF signals to provide wireless

communication services to subscribers.

[0029] Computer system 140 displays each subscriber as a circle of varying size depending on the accuracy of the signal throughout and around the cell-site. Preferably, subscriber data 330 includes information about a subscriber and the subscriber's location within or around the cellsite. One or more of a service provider's database, enhanced 911 support system, or global positioning system (GPS) may be used to generate subscriber data 330. Alternatively, other commercially known approaches may be used to obtain a subscriber's location within a defined geographical area.

[0030] Once computer system 140 displays the cell-site data stored in database 120, as shown in Fig. 3, the network manager can manipulate the data using one or more of the software tools. For controlling how the cell-site data appears on a display of computer system 140, the network manager can use a display information manager software tool.

[0031] The display information manager software tool is a filtering application, as described below in greater detail, that allows a user to view and manipulate a plurality of comparative visual data simultaneously on one screen. Using this software tool, a network manager can filter the quantity and control the opacity of the data displayed on computer system 140. As with the other software tools described herein, the display information manager software tool can be adapted for any application that involves viewing and manipulating a variety of complex data in an integrated format. For example, these applications may include air and ground traffic control, weather reporting, radio/television/data networks, and scientific applications such as molecular and biological modeling.

[0032] Fig. 3b illustrates one application of the display information manager software tool for controlling how computer system 140 displays the each type of cellsite data shown in Fig. 3a. In this example, computer system 140 displays the plurality of data in layers with the top layers being transparent in order to view all layers simultaneously. Transparent layering allows a network manager to simulate adjustments to the cellsite and view the impact of the adjustments on other cellsite data. Specifically, a network manager can view the cellsite data identified in Fig. 3b and adjust the intensities of these data using display information manager software tool control screen 350. By adjusting slider bars 351, the network manager can view cell site data 352, RF propagation data 353, user or subscriber data 354, map data 355, technician data 356, buildings or architectural data 357, connectivity data 358, labels 359, and switch borders 360. Control screen 350 also provides visual effects, such as check marks, for indicating to the network manager that a particular parameter intensity is at its highest or lowest position. In Fig. 3b, control screen 350 provides this indication for user data 354, map data 355, labels 359, and switch borders 360. The flexibility

of turning on or off any particular cellsite parameter allows the network manager to visualize the interaction between various cellsite parameters. This function further allows the network manager to provide an accurate, efficient, and effective evaluation of a cellsite and implement proper adjustments to ensure optimum cellsite planning and operation for subscribers. One of these adjustments may include tuning one or more antennas at the cellsite to modify existing RF propagation patterns.

[0033] To simulate cellsite tuning operations, a network manager can use the cellsite tuning software tool. The cellsite tuning software tool allows a network manager to simulate adjustments to a cellsite antenna and communicate these adjustments to the actual cell site operator in order to manually adjust the antenna on-site. In implementing this feature, a network manager, either stationed at the cellsite or remotely located, acquires RF propagation data for a particular sector. The RF propagation data allows a network manager to view RF coverage for a particular sector of the cellsite, as illustrated in Fig. 3a. Using graphical user interface 160 (shown in Fig. 1), the network manager can view a control screen, shown in Fig. 3c, for changing simulated cellsite conditions shown in Fig. 3a. Control screens for graphical user interface 160 vary depending on the desired cellsite operation the network manager chooses to modify. In Fig. 3c, for example, the network manager can make simulated antenna adjustments to various parameters that control RF propagation for a cellsite. The control screen in Fig. 3c includes a height icon 370, pitch icon 375, yaw icon 380, and power icon 385.

[0034] Height icon 370 allows a network manager to adjust the height of a simulated antenna 372 shown in Fig. 3a. Changing the height of simulated antenna 372 may also change other simulator parameters at the cell-site, such as RF coverage and border position.

[0035] Pitch icon 375 controls the simulation of the antenna pitch which is antenna revolution about a lateral axis. Yaw icon 380 controls the simulation of the antenna yaw which is antenna revolution about a vertical axis. Finally, power icon 385 allows the network manager to simulate an increase or decrease of antenna power intensity (i.e., simulating an adjustment to a power amplifier connected to the antenna). By increasing or decreasing the power, a cellsite antenna can transmit a stronger or weaker signal, respectively. The network manager can control the height, pitch, yaw and power by dragging a slider bar 390 (e.g., using a mouse pointer) between a first and second position. Each icon displays a numerical value associated with the position of the slider. By using the cellsite tuning software tool described herein, a network manager can see the effects of any adjustments made to a cellsite antenna.

[0036] As the network manager adjusts the parameters in Fig 3c, computer system 140 displays changes in RF coverage as an adjusted RF propagation signal 395

shown in Fig. 3a. The network operator can view the adjustments and make any necessary changes. Upon reaching a satisfactory adjustment to the antenna using the simulator, the network operator saves these changes in a memory and preferably communicates them to the cellsite in real-time (e.g. through a wireless communications link). Upon receiving these changes at the cellsite, an on-site technician makes the actual changes to the antenna or power amplifier consistent with the simulated changes. Preferably, an antenna mounting bracket for supporting the antenna includes calibrated markings that allow the technician to accurately make the requested adjustments to antenna height, yaw and pitch either electronically or manually. Alternatively, the simulated changes may be communicated to an automated system, such as a robotic system, that adjusts the cellsite equipment (i.e., the antenna and power amplifier) accordingly.

**[0037]** Network management system 100 has advantages over systems that require an on-site technician to physically make changes to an antenna and then test to see if the changes yield the desired results. This trial and error approach is very time consuming and also may not provide the most accurate cellsite adjustments. The broad range of data available through network management system 100 allows the network manager to plan adjustments based on actual cellsite characteristics. For example, viewing architectural as well as topographical data associated with the cellsite allows a network manager to see where possible transmission problems occur. In systems without the simulation capability, a technician may not be able to view from the cellsite where these obstructions or potential problems exist. The method of tuning an antenna at a cellsite using network management system 100 is described in detail below.

**[0038]** Fig. 4 provides a flowchart for illustrating a method of tuning an antenna at a cellsite consistent with the present invention. Initially, the network manager obtains RF propagation data measured at the cellsite (step 400). The network manager then manipulates the RF propagation data on computer system 140 to simulate an antenna parameter change at the cellsite (step 420). Subsequently, the simulated change is communicated to a cellsite controller (e.g., an on-site technician or computer controller), (step 440). Upon receiving the simulated change information from the network manager, the cellsite controller then makes actual adjustments to the cellsite hardware (i.e., antenna) to conform to the simulated changes (step 460). This method may be repeated for other parameters that require adjustment or modification at the cellsite.

**[0039]** Fig. 5a illustrates a cross-sectional viewer software tool for simulating a cross-sectional view of RF propagation at a cellsite consistent with the present invention. The cross-sectional viewer software tool allows a network manager to obtain detailed views of RF propagation data in a variety of planes. Typically,

network managers are unable to account for all possible RF obstructions or interferences from a plan view alone. By having access to both cross-sectional and plan views, the network manager can effectively plan and troubleshoot RF propagation problems. To facilitate viewing RF propagation coverage, the network manager has access to other cellsite data such as topographical and architectural information shown in Fig. 5a. In this example, the cellsite includes three different sectors labeled A, B, and C.

**[0040]** The cross-sectional viewer software tool allows the network manager to select an area of the simulated cellsite for a more detailed view. To select the desired area, the network manager chooses two reference points in the cellsite area. A first reference point 500, illustrated in Fig. 5a, is normally located in an area adjacent a cellsite antenna. A second reference point 510 is located in an area adjacent the boundary of RF propagation coverage. Preferably, the network manager selects the first and second reference points by mouse clicking each point. After the points are selected, the cross-sectional viewer software tool provides the network manager with a cross-sectional view of RF propagation coverage, as illustrated in Fig. 5b. In this figure, the simulated view includes an RF propagation wave 520 transmitted by an antenna 550, topographical data 530, and architectural data 540. Fig. 5b also includes a scale for antenna height and antenna distance from a point of reference on the display. In this example, the antenna is at a height of 152 feet and is approximately 16 miles away from an architectural obstruction. The cross-sectional illustration of RF propagation coverage may be represented in an absolute or relative scale. This simulated information allows a network manager to simply adjust antenna 550 to compensate for the obstruction. Typical network systems are unable to provide this level of detail to a network manager.

**[0041]** Fig. 6 is a flowchart illustrating a method of selecting a cross-sectional RF propagation area of a cellsite for viewing in a manner similar to that illustrated in Figs. 5a and 5b. The method begins by storing cellsite data in database 120 (step 600). As described above, cellsite data are obtained by commercially available systems and processes capable of electronically representing geographical area and RF propagation data. Upon acquiring the necessary information, the network manager can display the data in plan view on a display of computer system 140 (step 620). Using graphical user interface 160, the network manager can select two reference points of data on the display to view a cross-sectional area of the RF coverage between the selected reference points (step 640). Network management system 100 then generates a cross-sectional view of RF coverage between the selected points on computer system 140 (step 660). Network management system 100 also allows the network manager to select other cross-sectional views of RF coverage at the cellsite by selecting additional reference points. Essentially, the network



manager can manipulate a wide variety of data to effectively simulate cellsite operation.

[0042] The data browser software tool allows a user to categorically identify related portions of a large database to effectively navigate through and use the information stored in the database. To accomplish this objective, the data browser software tool uses a minimal number of windows to indicate the depth of hierarchy for one or more related database categories. Figs. 7 through 9 illustrate examples of how computer system 140 implements the data browser software tool for specific applications.

[0043] Fig. 7 illustrates a sector cellsite data browser software tool for simulating a plurality of RF propagation layers corresponding to respective antenna groupings at a cellsite consistent with the present invention. This cellsite data browser tool enables a network manager to view layers of RF coverage for different antenna groupings.

[0044] In high traffic urban areas, service providers typically use multiple RF voice channels to support a high density of callers. These areas are usually covered by several antennas arranged vertically and/or radially on a cellsite tower. A number of these antennas may have similar physical properties. For example, the cellsite may have six antennas where three of the antennas are at one height and the remaining antennas are at another height. The network manager can view the RF propagation data for the first three antennas and then view the RF propagation properties for the remaining three antennas. The cellsite data browser software tool allows a network manager to view the RF propagation characteristics for each group of antennas having similar heights in the above example as well as each antenna in the group. By viewing RF propagation from the antenna groups, the network manager can pinpoint which antenna or antenna grouping may need adjustment.

[0045] As illustrated in Fig. 7, a network manager can view RF coverage for one or more sectors represented by one or more antennas and also select which antenna grouping to view using numerical tabs 700. Numerical tabs 700 include tabs "1" to "3" which identify the hierarchical relationship between each antenna grouping. By selecting tab "3", for example, the network manager can review RF propagation data for antenna grouping 720 which consists of three antennas. In this example, antenna grouping 720 provides RF propagation for one of a plurality of voice channels supported by the cellsite. The RF propagation data shown for each antenna in Fig. 7 is transparent to allow a user to view topographical and architectural data associated with the cellsite.

[0046] As shown in Fig. 7, a first antenna 721 of antenna grouping 720 provides RF coverage for a first sector 740. A second antenna 722 and third antenna 723 of antenna grouping 720 covers a second sector 760 and third sector 780, respectively. Graphical user interface 160 (shown in Fig. 1) allows the network manager

to select other numerical tabs illustrated in Fig. 7 to view other antenna groupings. The display of other antenna groupings may be similar to that illustrated for antenna grouping 720. The numerical tab currently activated should indicate which antenna grouping is on the display. This feature can be accomplished using color codes or other type of visual effects. In addition, the cellsite data browser software tool not only displays the number of sectors, but also the size and shape of each sector as shown in Fig. 7. With the above-noted features, this particular data browsing tool allows a network manager to effectively troubleshoot antenna problems experienced at the cellsite and also make any necessary adjustments to improve RF coverage for a specified geographical area.

[0047] Fig. 8 is a flowchart illustrating a method of manipulating and displaying RF propagation data for selected antenna groups at a cellsite. The method begins with storing RF propagation data corresponding to each antenna and antenna group at a cellsite (step 800). Preferably, sonar mapping techniques are used to generate RF propagation data for each antenna and antenna group located at the cellsite. Subsequently, computer system 140 displays the RF propagation data for each antenna group (step 820). Finally, the network manager can manipulate the propagation data for each simulated antenna group on computer system 140 and make any necessary adjustments through graphical user interface 160 (step 840). Any changes that the network manager makes on the simulated display may be communicated to one or more cellsites in order to implement the simulated changes.

[0048] Fig. 9 provides another example of how a data browser software tool consistent with the present invention may be used to interpret and navigate through large amounts of data. In this example, computer system 140 uses the data browser software tool to identify sub-networks associated with a generic wireline communications network 900. Network 900 consists of a plurality of nodes including LAN-X2 node 910, TRK-1 node 920, TRK-2 node 930, XRT-1 node 940, LM-22 node 950, and RFM node 960. The plurality of nodes communicate with one another through trunk lines 970. Each of the network nodes shown in Fig. 9 are at the same hierarchical level within network 900. With the exception of LM-22 node 950, each node includes one or more sub-networks identified by numerical tabs 980. Hence, if a user selects tab "1" of LAN-X2 node 910 through graphical user interface 160, computer system 140 displays the first hierarchical sub-network level of the selected node. Accordingly, if a user selects tab "2" of LAN-X2 node 910, computer system 140 displays the second hierarchical level of the selected node. Similar to the example of Fig. 7, graphical user interface 160 uses visual effects to identify a selected hierarchical level displayed on computer system 140. For example, when a user selects tab "1" of LAN-X2 910, computer system 140 disables tab "1" (e.g., using a grey color) and keeps

the other tabs active (e.g., using a red color). Alternatively, the data browser software tool may be used in the medical field to show biological entity networks or in the utility field to show piping networks (e.g., hydro lines, oil refinery pipelines, etc.). Regardless of the application, the data browser software tool immediately indicates to a user the number of sub-layers associated with a main network layer. This feature allows the user to simultaneously view and navigate through multiple networks or groups of data using a single graphical user interface window generated by computer system 140.

**[0049]** The historical traffic performance software tool allows a user to simulate historical and current traffic patterns for a variety of applications. These applications may include air traffic control, wireless communications subscriber tracking, or any other application that involves tracking the movement of objects or people over time. Figs. 10a and 10b illustrate examples of how computer system 140 implements the historical traffic performance software tool for specific applications.

**[0050]** Fig. 10a illustrates a historical traffic performance viewer software tool for simulating a subscriber's location within or around a cellsite when placing a call consistent with the present invention. In this example, computer system 140 uses subscriber data to simulate subscriber location tracking when connection problems occur (i.e., when wireless communication subscribers encounter problems making calls on their mobile phones). This feature provides the network manager with a tool for monitoring subscriber traffic patterns during various time periods. During these periods, system 100 implements the historical traffic performance tool to identify a problem subscriber location and determine appropriate adjustments. An enhanced 911 service, for example, may be used to identify a subscriber's locations within a specified geographical area. The enhanced 911 service locates a subscriber using a method such as triangulation and allows for the location of one or more subscribers to be defined over a period of time. Although enhanced 911 service is not the only way of identifying a subscriber's location within a geographical area, this particular service provides an accurate and efficient method of acquiring this information.

**[0051]** Preferably, a network manager accumulates subscriber and subscriber location data over time to generate a view of subscriber traffic patterns and possible problem areas. As with the embodiments discussed above, additional cellsite data may be used in conjunction with the subscriber and subscriber location data to provide the network manager with an overall picture of cellsite operations. Included in this additional data may be topographical, architectural, and street map data.

**[0052]** Referring now to Fig. 10a, a network manager can view the location of a first subscriber 1000 in relation to one or more antennas fixed at a cellsite using the graphical user interface capabilities of the historical traffic performance software tool. By viewing the cellsite information of Fig. 10a, the network manager can deter-

mine which subscribers are receiving service and which subscribers are not. For example, first subscriber 1000 in Fig. 10a can successfully connect with the cellsite based on their location within the cellsite. However, a second subscriber 1010 cannot connect to the cellsite because of architectural obstruction 1020. Upon viewing this problem, the network manager may adjust one or more of the antennas in one or more cellsites to ensure that second subscriber 1010 can successfully connect to the network.

**[0053]** Using the cellsite tuning software tool illustrated in Figs. 3a and 3b, the network manager can also simulate antenna adjustments and view the resulting RF propagation coverage. When the network manager has made the appropriate adjustments, this information can be forwarded to one or more cellsites to allow the appropriate adjustments to be made.

**[0054]** Fig. 10b is a control screen for controlling parameters associated with the cellsite of Fig. 10a over a period of time. This control screen may also be used for other software tools described herein to control simulated cellsite operations over a period of time. For the historical traffic performance software tool, the control screen allows the network manager to select one or more locating actions 1030 to locate the position of one or more subscribers within and around the cellsites during a selected period of time. These locating functions include playing a simulated image of subscriber movement within the cellsite during a specified period of time. The simulated subscriber movement can be played in real-time. The network manager can also fast forward, rewind, or stop the simulation using locating functions 1030.

**[0055]** The network manager can adjust a slider bar 1040 (e.g., using a mouse) for viewing cellsite operation during a selected time period. This feature allows the network manager to determine when RF coverage is troublesome for certain geographical areas within the cellsite. Upon identifying this information, the network manager can make adjustments during critical time periods to ensure that subscribers have sufficient coverage for high traffic periods. The historical traffic performance software tool enhances the accuracy of network management system 100 by allowing the network manager to track RF coverage for a period of minutes or even seconds on a clock display 1050. This allows a network manager greater flexibility when adjusting cellsite parameters to accommodate a large volume of subscribers within a specified time period.

**[0056]** As described herein, data manipulation and visualization software tools consistent with the present invention allow a user to view, manipulate and organize complex data in a simulated environment. These software tools may be used for a variety of applications, such as to effectively plan and operate one or more cellsites within a wireless network. Using this application as an example, a network manager can simulate desired antenna tuning adjustments before actually adjusting

the cellsite antenna. In addition, the data manipulation and visualization tools provide the network manager with detailed views of RF coverage in a variety of planes to effectively troubleshoot RF propagation problems. Further, the network manager can use these tools to browse RF coverage generated by a cellsite, and more specifically, each cellsite antenna grouping. The software tools also facilitate tracking a subscriber's location over a specified period of time to locate potential problems for subscribers using the network. Finally, the software tools employed by system 100 allow a network manager to view a plurality of cellsite data on a single screen to effectively monitor how certain adjustments affect existing cellsite conditions.

[0057] While there has been illustrated and described preferred embodiments and methods of the present invention, those skilled in the art will understand that various changes and modifications may be made, and equivalents may be substituted for elements thereof, without departing from the true scope of the invention.

[0058] In addition, many modifications may be made to adapt a particular element, technique or implementation to the teachings of the present invention without departing from the central scope of the invention. Therefore, this invention should not be limited to the particular embodiments and methods disclosed herein, but should include all embodiments falling within the scope of the appended claims.

#### Claims

1. A data manipulation and visualization tool for simulating an operational characteristic of a cellsite, comprising:
  - means for storing data corresponding to the operational characteristic of the cellsite;
  - means for displaying the data;
  - means for manipulating the data to simulate the operational characteristic of the cellsite;
  - and
  - means for viewing the simulated operation of the cellsite.
2. The tool of claim 1 further comprising means for communicating with a remote cellsite to send and receive the data corresponding to an operational characteristic of the cellsite over a communications channel.
3. The tool of claim 1 wherein the storing means includes means for integrating a plurality of data corresponding to a first cellsite operational characteristic and a plurality of data corresponding to a second cellsite operational characteristic into a single database.
4. The tool of claim 2 wherein the storing means

includes means for storing RF propagation data received over the communications channel.

5. The tool of claim 2 wherein the storing means includes means for storing antenna parameter data received over the communications channel.
6. The tool of claim 5 wherein the manipulating means includes means for simulating a change to an operational characteristic of a cellsite antenna using the antenna parameter data.
7. The tool of claim 1 wherein the manipulating means includes a graphical user interface.
8. The tool of claim 2 wherein the communicating means includes means for communicating data representing the simulated operational characteristic to the cellsite.
9. The tool of claim 8 wherein the communicating means further includes means for communicating data representing the simulated operational characteristic to the cell site in real-time.
10. The tool of claim 3 wherein the integrating means includes means for integrating a plurality of cellsite architectural data, a plurality of cellsite topographical data, and a plurality of RF propagation data in the single database.
11. The tool of claim 10 wherein the manipulating means includes means for simulating a cross-section of RF propagation at the cellsite in a variety of planes using the plurality of RF propagation data and at least one of the plurality of cellsite architectural data and the plurality of cellsite topographical data.
12. The tool of claim 10 wherein the manipulating means includes means for simulating a RF propagation for each of a plurality of antennas at the cellsite using the plurality of RF propagation data, the simulating means including means for visually layering the RF propagation data for each antenna in a transparent format.
13. The tool of claim 12 wherein the visually layering means includes means for representing each layer with a visual identifier.
14. The tool of claim 13 wherein the manipulating means includes means for selecting each layer for viewing the RF propagation corresponding to one of the plurality of antennas.
15. A cellsite for supporting a wireless communication system, comprising:

- means for receiving simulated operational data from a remote site;  
 means for modifying a cellsite parameter to conform to the simulated operational data; and  
 means for communicating a plurality of modified cellsite parameter data to the remote site.
16. The cellsite of claim 15 further comprising means for measuring radio frequency propagation from an antenna located at the cellsite.
17. The cellsite of claim 16 wherein the antenna includes an antenna mounting bracket with parameter markings for facilitating manual antenna adjustment.
18. A method of data manipulation and visualization for simulating an operational characteristic of a cellsite, comprising the steps of:
- storing data corresponding to the operational characteristic of the cellsite;
  - displaying the data;
  - manipulating the data to simulate the operational characteristic of the cellsite; and
  - viewing the simulated operation of the cellsite.
19. The method of claim 18 further comprising the step of communicating with a remote cellsite to send and receive the data corresponding to an operational characteristic of the cellsite over a communications channel.
20. The method of claim 18 wherein the storing step includes the step of integrating a plurality of data corresponding to a first cellsite operational characteristic and a plurality of data corresponding to a second cellsite operational characteristic into a single database.
21. The method of claim 19 wherein the storing step includes the step of storing RF propagation data received over the communications channel.
22. The method of claim 19 wherein the storing step includes the step of storing antenna parameter data received over the communications channel.
23. The method of claim 22 wherein the manipulating step includes the step of simulating a change to an operational characteristic of a cellsite antenna using the antenna parameter data.
24. The method of claim 18 wherein the manipulating step includes the step of using a graphical user interface.
25. The method of claim 19 wherein the communicating
- step includes the step of communicating data representing the simulated operational characteristic to the cellsite.
26. The method of claim 25 wherein the communicating step further includes the step of communicating data representing the simulated operational characteristic to the cell site in real-time.
27. The method of claim 20 wherein the integrating step includes the step of integrating a plurality of cellsite architectural data, a plurality of cellsite topographical data, and a plurality of RF propagation data in the single database.
28. The method of claim 27 wherein the manipulating step includes the step of simulating a cross-section of RF propagation at the cellsite in a variety of planes using the plurality of RF propagation data and at least one of the plurality of cellsite architectural data and the plurality of cellsite topographical data.
29. The method of claim 27 wherein the manipulating step includes the step of simulating a RF propagation for each of a plurality of antennas at the cellsite using the plurality of RF propagation data, the simulating step including the step of visually layering the RF propagation data for each antenna in a transparent format.
30. The method of claim 29 wherein the visually layering step includes the step of representing each layer with a visual identifier.
31. The method of claim 13 wherein the manipulating step includes the step of selecting each layer for viewing the RF propagation corresponding to one of the plurality of antennas.
32. A method for tuning an antenna located at a cell-site, comprising the steps of:
- generating radio frequency propagation data for the antenna located at the cellsite;
  - manipulating the radio frequency propagation data on a computing device to simulate a change to a parameter of the antenna;
  - communicating a plurality of data to a cellsite controller representing the simulated change; and
  - modifying the antenna parameter at the cellsite to correspond to the communicated simulated change.
33. The method of claim 32 wherein the step of generating radio frequency propagation data includes the step of measuring radio frequency data at the cell-

site.

34. The method of claim 32 wherein the step of manipulating the radio frequency propagation data includes the step of displaying the radio frequency propagation data with at least one of a plurality of topographical data and architectural data. 5
35. The method of claim 32 wherein the step of modifying the antenna parameter includes the step of manually adjusting the antenna at the cellsite to conform to the communicated simulated change. 10
36. A method for simulating multiple views of RF coverage for a cellsite, comprising the steps of: 15
- storing data corresponding to an operational characteristic of a cellsite in a memory;
  - displaying the data in a plan view on a display;
  - selecting at least two points on the display of the data using a graphical user interface; and 20
  - generating a cross-sectional view of the data between the selected points.
37. A method for simulating a plurality of RF propagation layers corresponding to a plurality of antennas arranged at a cellsite, comprising the steps of: 25
- storing a plurality of RF propagation data corresponding to each of the plurality of antennas arranged at the cellsite; 30
  - displaying the RF propagation data; and
  - manipulating the RF propagation data to simulate a RF propagation layer for each of a plurality of antennas, including the steps of: 35
    - visually layering the RF propagation data for each antenna in a transparent format;
    - representing each layer with a visual identifier; and 40
    - selecting each layer for viewing the RF propagation corresponding to one of the plurality of antennas.
38. The method of claim 37 wherein the manipulating step includes the step of using a graphical user interface. 45

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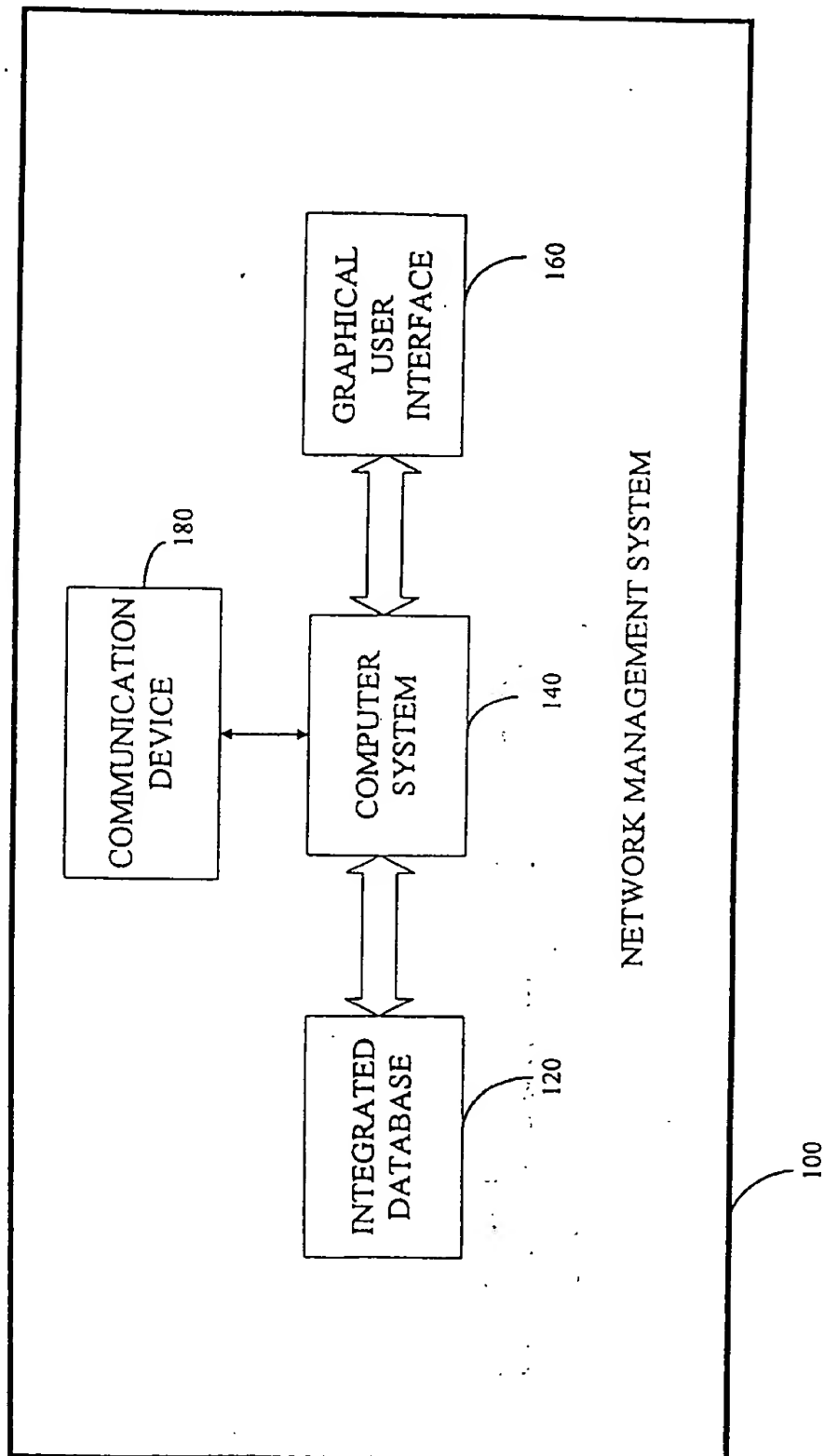


FIG. 1

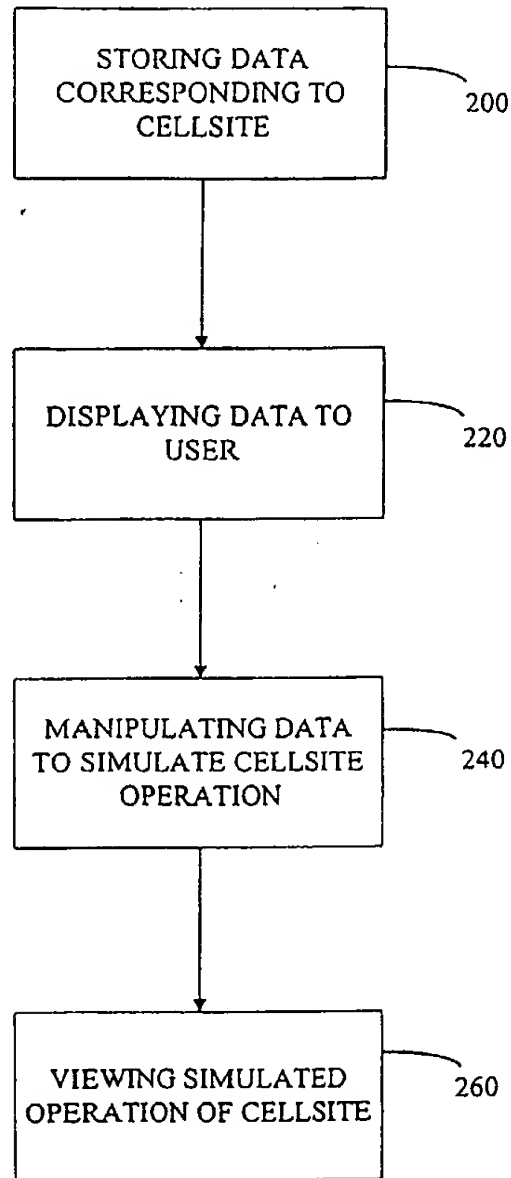
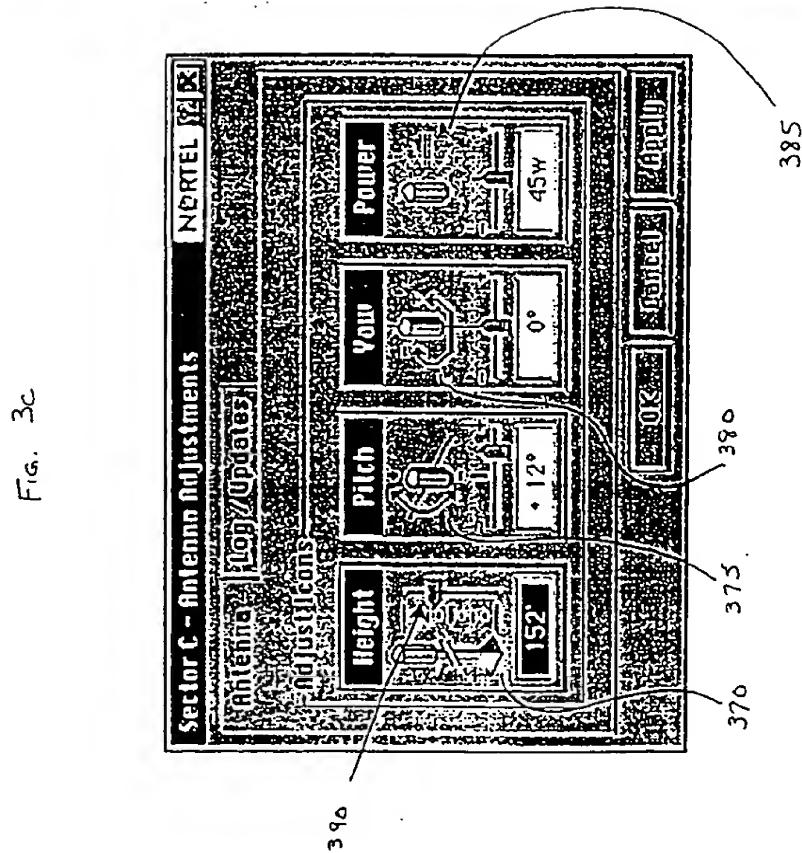
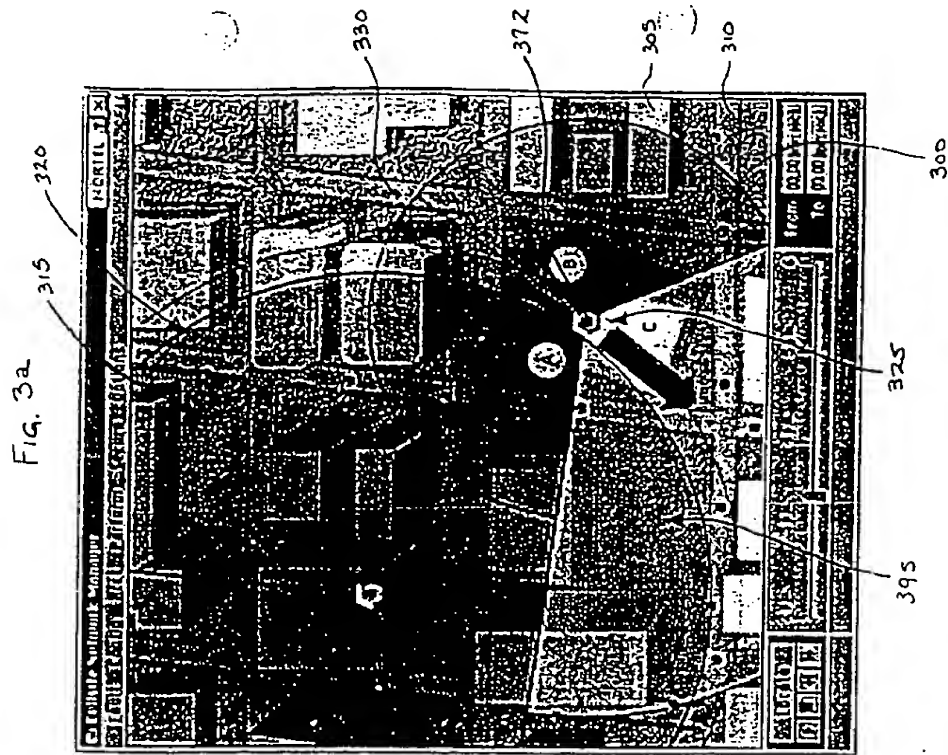
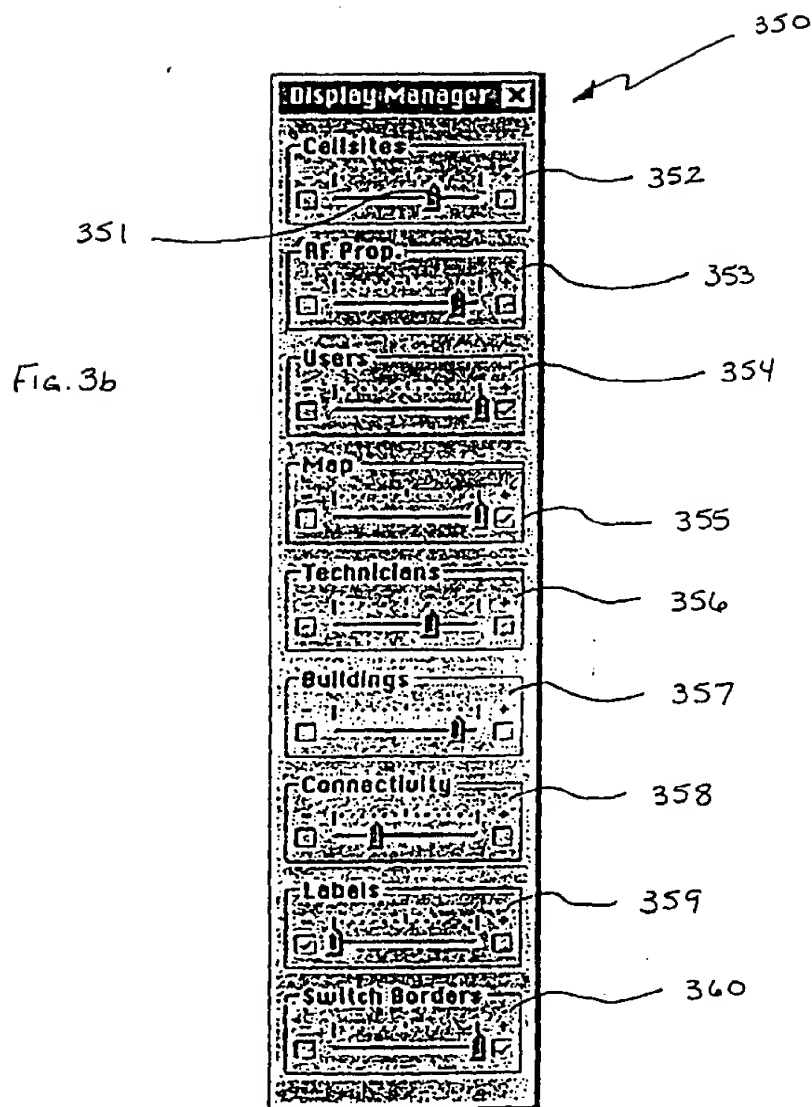


FIG. 2







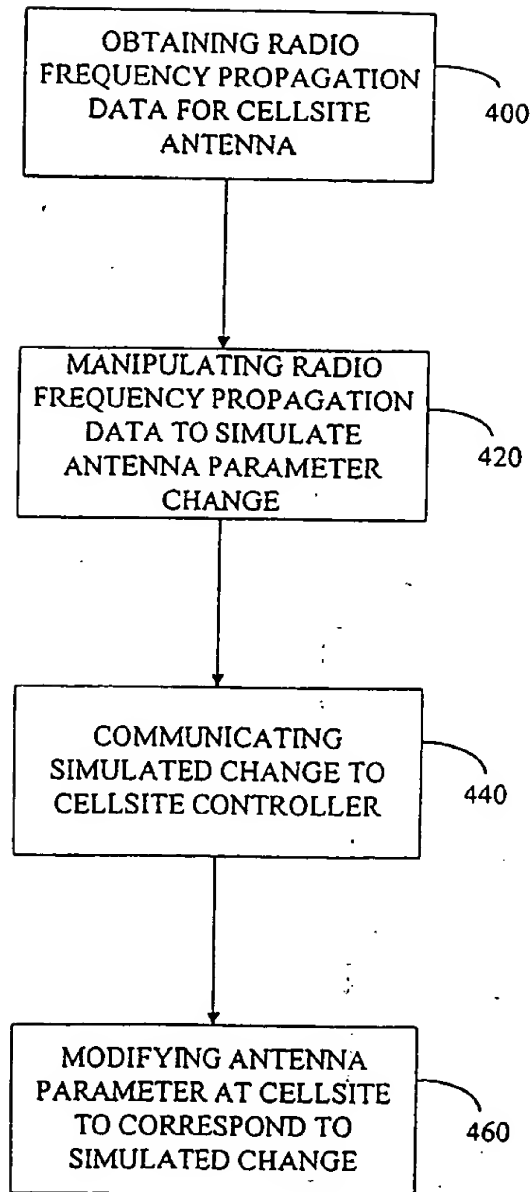


FIG. 4

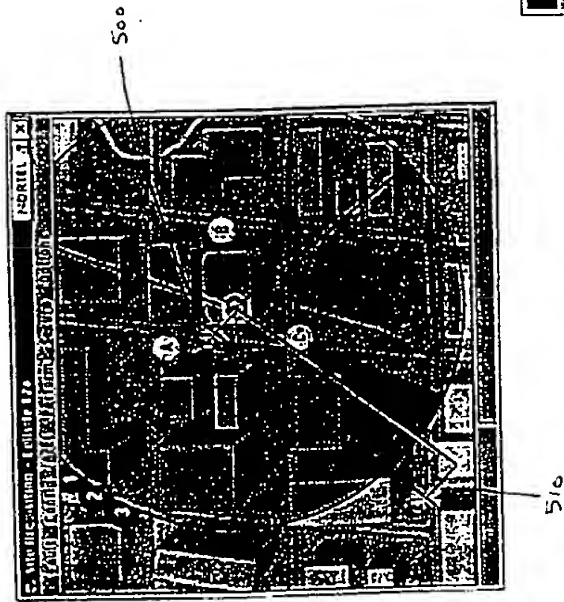
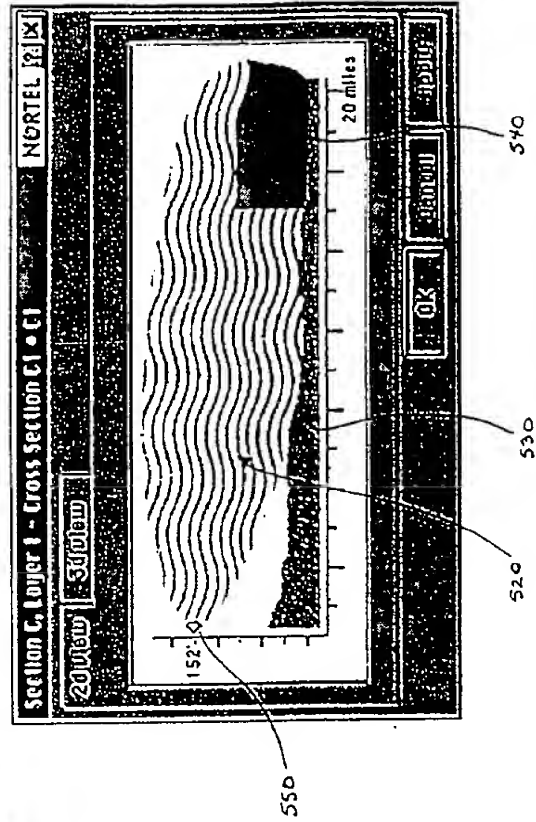


Fig. 5a

Fig. 5b



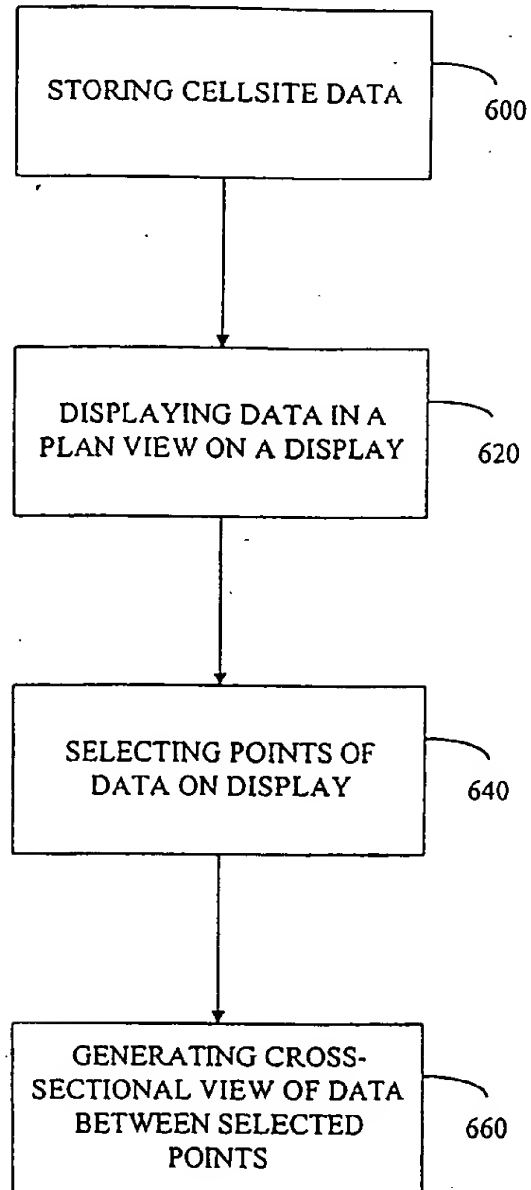
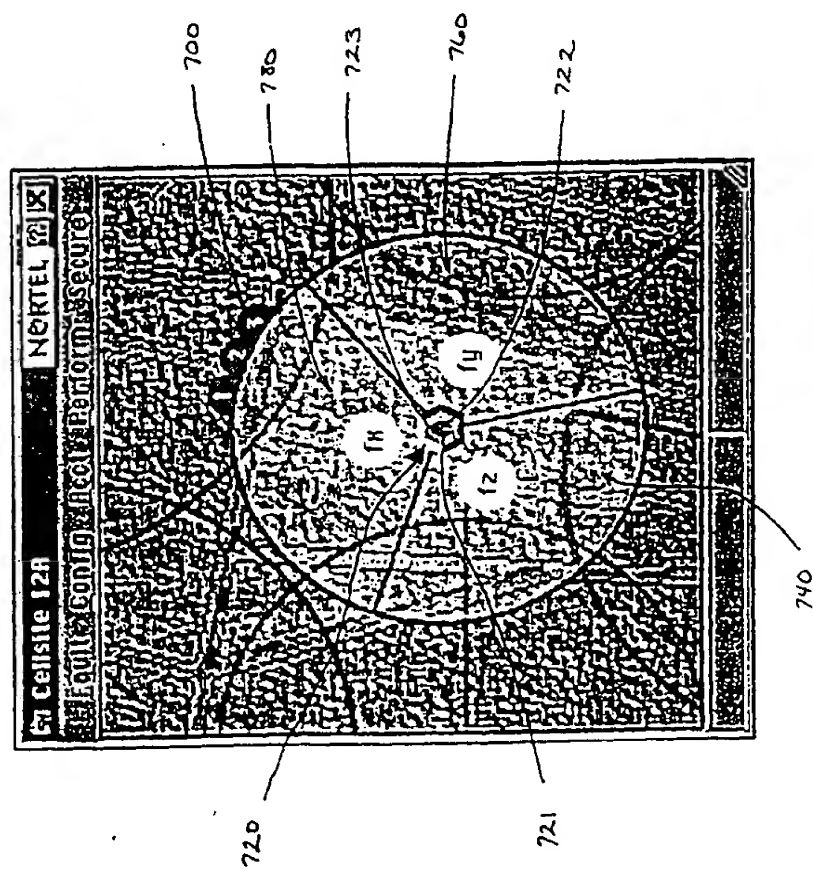


FIG. 6

FIG. 7



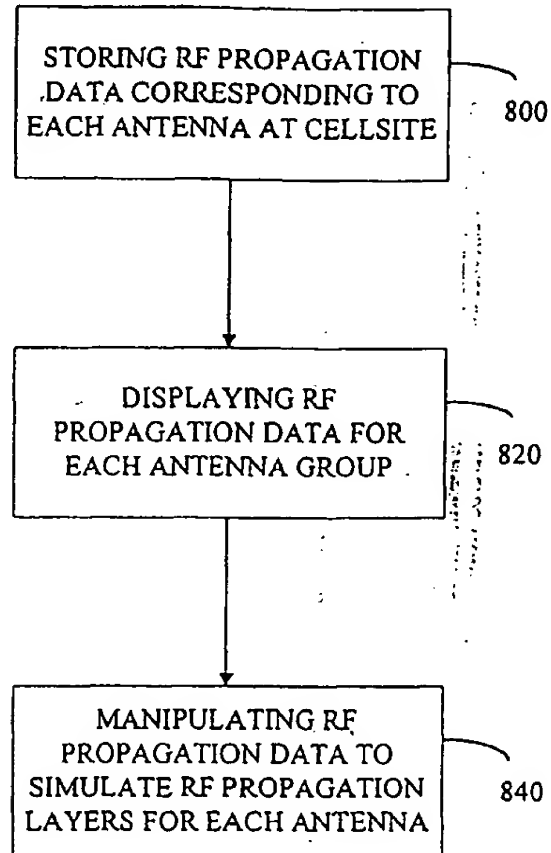
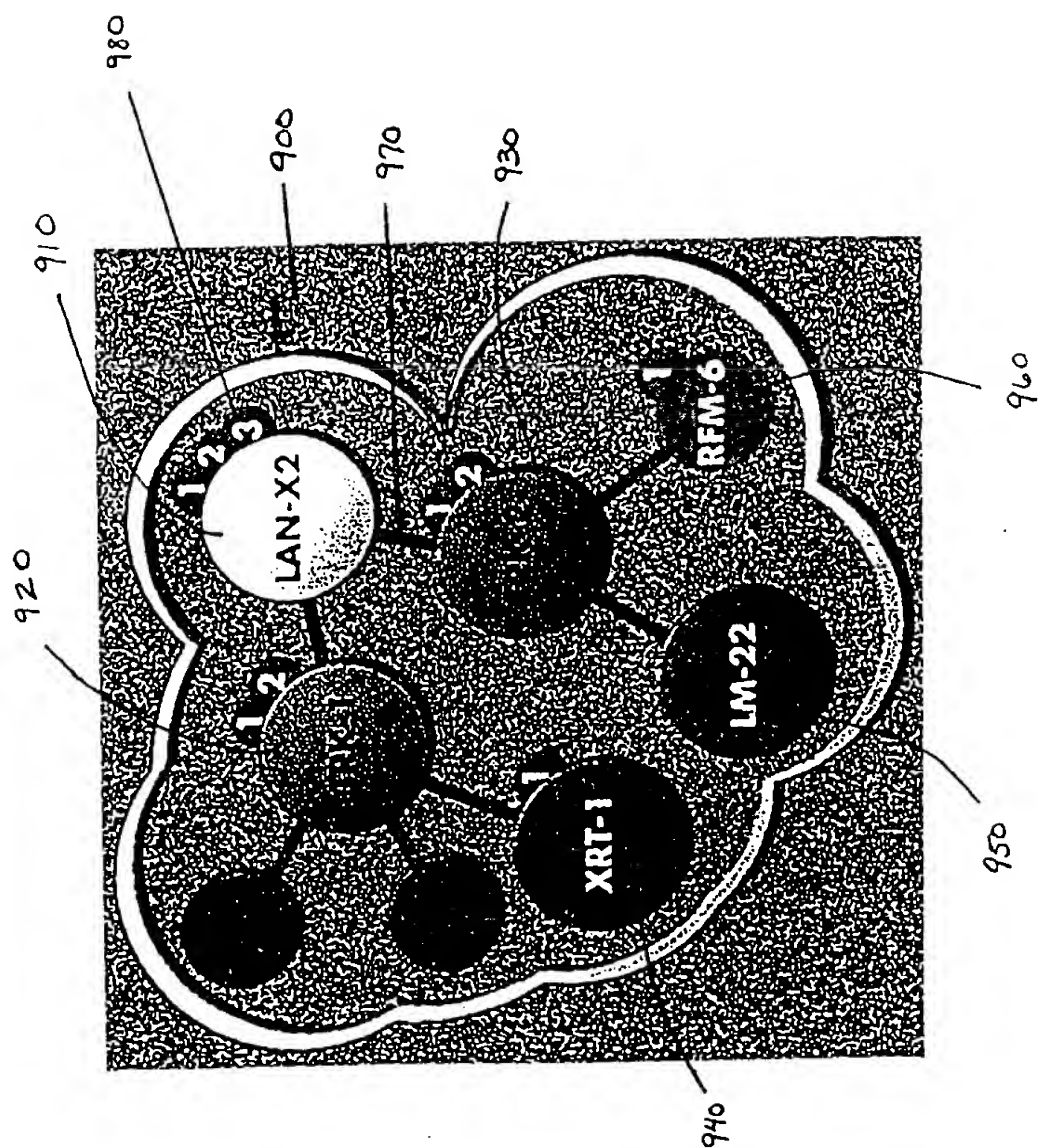


FIG. 8

FIG. 9



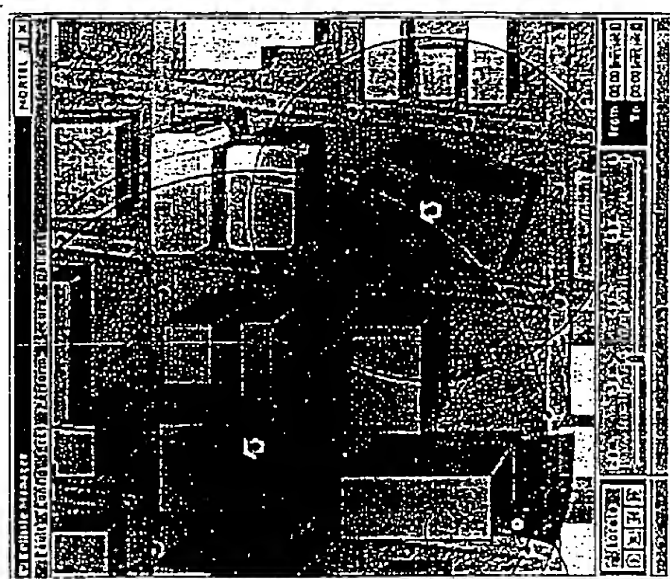


Fig. 10a

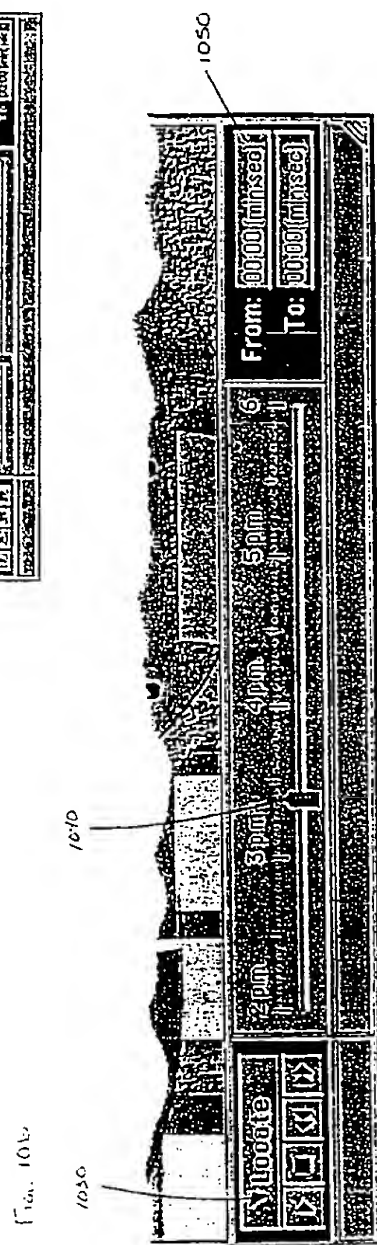
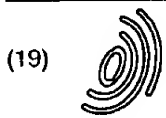


Fig. 10b





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(54) **Data manipulation and visualization apparatus for cellular network planning and operation**

(57) Data manipulation and visualization tools for simulating the planning and operation of one or more cellsites within a wireless network include an integrated database of cellsite information such as topographical, architectural, and RF propagation data. The tools retrieve and manipulate this data through graphical user interface software executed by a computing device. Using the graphical user interface, a user may simulate the operational characteristics of a cellsite, such as an antenna adjustment at the cellsite, and view cellsite parameters on a computer screen, such as the resulting RF propagation patterns from the antenna adjustment.

**EP 0 928 121 A3**



European Patent  
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# EUROPEAN SEARCH REPORT

Application Number

EP 98 12 4851

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The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>11 January 2000</b>	Examiner <b>Behringer, L.V.</b>
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document</p>			

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